29. (Twice Amended) The apparatus of claim 24 wherein said multilevel optical phase element is multilevel in two orthogonal directions.

30. (Twice Amended) The apparatus of claim 24 wherein said light source comprises a plurality of subsources each subsource having a different spectral distribution.

31. (Twice Amended) The apparatus of claim 30 wherein each said subsource is a light emitting diode.

32. (Twice Amended) The apparatus of claim 30 wherein each said subsource is a laser.

REMARKS

The remainder of this Amendment is set forth under appropriate subheadings for the convenience of the Examiner.

I. Amendments to the Specification

Applicant has amended page 21, line 20 of the specification to indicate that the condensing lens in Fig. 8 is labeled with the number "70" instead of the number "30." Support for this amendment can be found in Fig. 8.

Applicant has amended page 21, line 24 of the specification to indicate that the imaged source in Fig. 8 is labeled with the number "44" instead of the number "22." Support for this amendment can be found in Fig. 8 and on page 22, lines 2-4 of the specification.

Applicant has amended the formula for magnification which appears at the bottom of page 23 of the specification. Support for the amended formula for magnification can be found in Claim 30 in the claims as originally filed.

II. Claim Amendments

Applicant has amended Claims 1, 10, 15, and 24 to indicate that the multilevel optical phase element diffracts each wavelength of interest from the light source into a plurality of

diffraction orders. Support for this amendment can be found on page 5, lines 2-6 of the specification.

Applicant has amended Claims 1, 10, 15, and 24 such that the claims more clearly represent Applicants's invention. Claim 1, 10, 15 and 24 have been amended to indicate that the multilevel optical phase element projects, rather than focuses, the dispersed light onto an image plane. Support for this amendment can be found in Figs. 7 and 8 which show a block diagram of an embodiment of the invention, and on page 20, line 15 to page 21, line 17, which describes Fig. 7, and page 21, line 18 to page 25, line 13, which describes Fig. 8. As can be seen from Figs. 7 and 8, there is no element that focuses light leaving multilevel optical phase element 11. Rather light from leaving multilevel optical phase element 11 is projected onto an image plane containing modulating display 15.

Claim 1 has also been amended to indicate that the light modulating display is positioned within the near field region of the multilevel optical phase element. Support for this amendment can be found on page 5, line 26 to page 6, line 3 of the specification.

Applicant has amended Claims 2 and 16 to correct the formula for the distance "Z" at which the display is positioned from the multilevel optical phase element. Support for this amendment can be found on page 20, lines 6-8 of the specification.

Applicant has amended Claim 8 to correct the formula for the distance "Z" at which the display is positioned from the multilevel optical phase element. Support for this amendment can be found on page 25, line 21 to page 26, line 16 of the specification.

Applicant has amended Claims 12 and 26 to correct the formula for the distance "Z" at which the display is positioned from the multilevel optical phase element. Support for this amendment can be found on page 26, line 16 to page 7 of the specification.

Claim 12 has also been amended to depend from Claim 10 and to indicate that the plurality of focusing elements includes a plurality of lenslets. Support for this amendment can be found on page 21, lines 18-21 of the specification and in Fig. 8.

Applicant has amended Claims 15, 16, and 18-32 to replace the term "display system" with the term "display apparatus."

III. Objection to Claims 8, 9, 12 and 26 Under 37 C.F.R. § 1.75

The Examiner objects to Claims 8 and 9 because they are a substantial duplicate of Claim 2. Applicant has canceled Claim 9 and amended Claims 2 and 8 such that the formulas for the distance "Z" of the light modulating display from the multilevel optical phase element in each claim are different. Therefore, Claims 2 and 8 are no longer substantial duplicates.

The Examiner objects to Claim 12 because it is a substantial duplicate of Claim 11. Applicant has amended Claim 12 such that the formulas for the distance "Z" of the light modulating display from the multilevel optical phase element in Claims 11 and 12 are different. Therefore, Claims 11 and 12 are no longer substantial duplicates.

The Examiner objects to Claim 26 because it is a substantial duplicate of Claim 25. Applicant has amended Claim 26 such that the formulas for the distance "Z" of the light modulating display from the multilevel optical phase element in Claims 25 and 26 are different. Therefore, Claims 25 and 26 are no longer substantial duplicates.

IV. Rejection of Claims 1, 3-7, 10, 15, 19-24, and 27-32 Under 35 U.S.C. § 103(a) Over Canon, J.P. A 62-293222 (hereinafter "CANON '222") in view of Gal, U.S. Patent No. 5,497,269 (hereinafter "Gal")

A. Summary of the Examiner's Rejection

The Examiner states that CANON '222 discloses the invention substantially as claimed except that CANON '222 discloses a blazed grating and refractive lenses instead of Applicant's multilevel phase element for dispersing and focusing light. However, the Examiner states that Gal teaches that the function of dispersion and focusing can be integrated into a multilevel phase element.

B. Summary of Applicant's Invention

Applicant claims an apparatus and a method for displaying a color images. The apparatus (Claim 15, as amended) and method (Claim 1, as amended) utilize a light source that emits a plurality of wavelengths of interest and a multilevel optical phase element that receives light from a light source. The multilevel optical phase element disperses each wavelength of interest

by diffraction into a plurality of diffraction orders and projects the dispersed light onto an image plane. The apparatus also includes a light modulating electronic display that has a plurality of pixel elements in which each pixel element is assigned to transmit a predetermined spectral region. The light modulating electronic display is positioned within the near field region of the multilevel optical phase element so as to receive the dispersed light from the multilevel optical phase element.

The apparatus and method may also include a plurality of focusing elements positioned so as to focus light from the light source before the light is received by the multilevel optical phase element (Claims 24 and 10, as amended).

C. Advantages of Applicant's Invention

Applicant's invention provides a novel display apparatus for effectively concentrating each wavelength of interest of an incident light to be employed in forming an image onto an appropriate color pixel of a light modulating display. For example, all of the spectral region represented by red light is concentrated such that it only illuminates a pixel region corresponding to the red component (see page 7, lines 3-16 of the specification). Applicant discloses that this effect depends on the relative depths of the levels of each grating period of the diffractive optical phase element and on the depth of a zero order phase shifter placed in the path of the light exiting the diffractive optical phase element (page 10, lines 23-27 of the specification). Although this example utilizes a zero order phase shifter, Applicant has disclosed on page 18, paragraph 2 of the specification that by setting the modulation display at an appropriate distance, no zero order phase shifter is necessary.

In a color display system, such as a system that utilizes an LCD panel to control the transmission of light, Applicant's multilevel optical phase element eliminates the need for micro-filters and allows the theoretical light utilization to approach 100% (see page 7, lines 16-20 of the specification). Light utilization in color displays that use micro-filters is only about 10% efficient (see page 2, lines 16-32 of the specification). Thus, Applicant's invention dramatically improves light utilization in color displays.

D. Summary of the Cited References

1. CANON '222

CANON '222 teaches a light-valve color display device that utilizes a convergent refractive optical element 5, such as a lenticular plate, and a diffraction grating 6 (CANON '222 translation, section entitled "Method to Solve the Problems"). White light is transmitted through the refractive optical element 5 and diffracted into spectral components (red, green and blue light) by the diffraction grate 6. Most of the light energy is concentrated into the ± 1st orders (CANON '222 translation, section entitled "Examples," paragraph 3). Red, green and blue spectrum beams of respective ± 1st order diffracted beams are made incident upon three light valves (3-1, 3-2, and 3-3). Zero order and ± 2nd order or greater diffracted beams are not utilized and their transmission is interrupted by a douser (CANON '222 translation, section entitled "Examples," paragraph 4). The diffraction grating disclosed in CANON '222 is a conventional surface relief, double-blazed grating that does not have multiple levels.

2. Gal

Gal teaches an array of dispersive microlenses that can be used to combine a plurality of different emitted wavelengths of light into a single bandwidth of light at an image plane blur spot (Gal, Col. 2, lines 31-35). Dispersive lenses are made by combining a plano convex microlens having a concave surface with a dispersion producing blazed diffraction grating surface configuration (Gal, Col. 12, lines 56-65 and Figs. 11-13). The curved surface 142 of the dispersive microlens is approximated by a series of discrete levels 142A, 142B, 142C, etc. (Gal, Col. 13, lines 44-55 and Fig. 19). The dispersive microlens transmits a selected bandwidth of light to a much smaller pixel blur spot in a plane space at a selected distance from th microlens (Gal, Col. 13, lines 56-60). Thus, the microlens array disclosed by Gal reduces the size of an image transmitted.

C. The combination of the cited references does not teach all of the elements of Applicants apparatus or method.

Applicant claims an apparatus and a method for displaying a color image that utilizes a multilevel optical phase element that diffracts each wavelength of interest in a light incident upon it into a plurality of diffraction orders.

The apparatus for displaying a color image disclosed by CANON '222 utilizes a conventional surface relief double blazed diffraction grating that diffracts light primarily into the ± 1st orders (CANON '222, Example Section, paragraph 3). CANON '222 does not disclose a diffraction element that has multiple levels.

Gal discloses a microlens in which the surface of the microlens is blazed so that the lens diffracts incident light. The curved surface of the microlens can be approximated by using a number of discrete levels. Thus, the multiple levels of the microlens taught by Gal function as a focusing element rather than a diffractive element. To achieve diffraction of light incident upon the microlens, Gal teaches that the dispersive surface of the microlens is a blazed. and, consequently, disperse the incident light primarily into one diffraction order.

CANON '222 does not teach or suggest an optical phase element that has multiple levels. Gal does not remedy the deficiencies of CANON '222 because the multilevel dispersive microlenses taught by Gal do not carry out the same function as Applicant's multilevel optical phase element. In particular, the multilevel dispersive microlenses taught by Gal do not diffract each wavelength of interest from a light source into a plurality of diffraction orders. Nor does Gal teach or suggest how to modify the multilevel dispersive microlenses such that they would diffract wavelengths of interest in an incident light into a plurality of diffraction orders. Since CANON '222 and Gal, either alone or in combination, do not teach or suggest an optical phase element that has multiple levels and diffracts light into a plurality of diffraction orders, the combination of CANON '222 and Gal does not teach all of the elements of Applicant's claimed apparatus or method. Therefore, Applicant's display apparatus and method are non-obvious over the cited art. Therefore, Applicant respectfully requests that the rejection of Claims 1, 3-7, 10, 15, 20-24, and 27-32 under 35 U.S.C. § 103(a) be reconsidered and withdrawn.

V. Rejection of Claims 2, 8, 9, 11-14, 16-19, 25 and 26 Under Obviousness-Type Double Patenting

The Examiner has rejected Claims 2, 8, 9, 11-14, 16-19, 25 and 26 under the judicially created doctrine of obviousness-type double patenting over Claims 1, 8, 9, 10, 12-14, 16-19, 25 and 26 of U.S. Application No. 08/443,180, now U.S. Patent No. 6,417,967.

Applicant have filed a terminal disclaimer herewith to overcome the rejection.

SUMMARY AND CONCLUSIONS

Applicant's display apparatus and method are non-obvious over the cited references because CANON '222 does not teach a multilevel optical phase element and Gal does not teach an optical phase element that has multiple levels and diffracts wavelengths of interest from light incident upon it into a plurality of diffraction orders.

In view of the above amendments and remarks, it is believed that all claims are in condition for allowance, and it is respectfully requested that the application be passed to issue. If the Examiner feels that a telephone conference would expedite prosecution of this case, the Examiner is invited to call the undersigned at (978) 341-0036.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By Theresa A. Devlin
Theresa A. Devlin
Registration No. 45,361
Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133
Dated: 11/5/02

MARKED UP VERSION OF AMENDMENTS

Specification Amendments Under 37 C.F.R. § 1.121(b)(1)(iii)

Replace the paragraph at page 21, line 18 through page 22, line 4 with the below paragraph marked up by way of bracketing and underlining to show the changes relative to the previous version of the paragraph.

Referring to Fig. 8, an embodiment which increases the extended source performance includes a lenslet array 40 (in one embodiment cylindrical lenslets), placed between the condensing lens [30] 70 and the multilevel phase element 11. The focal length of each lenslet 42 is F_m, and the distance between the lenslet array 40 and the multilevel phase element 11 is $Z_s + F_m$. Thus, Z_s is the distance between the imaged source [22] 44 and the multilevel phase element 11. Each lenslet 42 [focusses] focuses an image 44 of the extended source, S_c, at a distance F_m from the lenslet array 40. Each of these imaged sources 44 will be of physical dimensions, S_m, in the x-dimension, where $S_m = (F_m S_c/F_c)$ centered about the optical axis of the respective lenslet 42.

Replace the paragraph at page 23, line 12 through page 24, line 2 with the below paragraph marked up by way of bracketing and underlining to show the changes relative to the previous version of the paragraph.

The last exponential term indicates that the period of the light distribution at the optimum Z distance is no longer equal to the period of the original phase grating. In effect, free-space propagation from a source 10' located a finite distance from the grating 11 results in a magnification. This magnification, M, is given by the equation:

$$\left[\frac{1}{M} = 1 = \frac{Z}{Z_s} \right]$$

$$M = 1 + \frac{Z}{Z_s}$$

Note that for a finite source distance, Z_s, the magnification factor is greater than one.

Claim Amendments Under 37 C.F.R. § 1.121(c)(1)(ii)

1. (Twice Amended) A method for displaying a color image comprising the steps of: illuminating a multilevel optical phase element with a light source having a plurality of wavelengths of interest, said multilevel phase element dispersing [light] each wavelength of interest from said light source by diffraction into a plurality of diffraction orders and [focusing] projecting the dispersed light onto an imaging plane; and actuating a light modulating display in the imaging plane having a plurality of pixel elements, each said pixel element assigned to transmit a predetermined spectral region, positioned within the near field region of said multilevel [display] optical phase element so as to receive said dispersed and focused light from said multilevel optical phase element.

2. (Amended) The method of claim 1 wherein said display is positioned at a distance Z from said multilevel optical phase element, wherein Z is determined by the relationship:

$$\left[\frac{T^2}{3\lambda_{long}} < Z < \frac{2T^2}{3\lambda_{short}} \right]$$

$$\frac{2T^2}{3\lambda_{long}} < Z < \frac{2T^2}{3\lambda_{short}}$$

wherein T is the periodicity of said multilevel optical phase element, λ_{Long} is the longest wavelength of said plurality of wavelengths of interest and λ_{Short} is the shortest wavelength of said plurality of wavelengths of interest.

8. (Amended) The method of claim [2] 1 wherein said display is positioned at a distance Z from said multilevel optical phase element, wherein Z is determined by the relationship:

$$\left[\frac{T^2}{3\lambda_{long}} < Z < \frac{2T^2}{3\lambda_{short}} \right]$$

$$\frac{T^2}{3\lambda_{long}} < Z < \frac{T^2}{3\lambda_{short}}$$

wherein T is the periodicity of said multilevel optical phase element, λ_{Long} is the longest wavelength of said plurality of wavelengths of interest and λ_{Short} is the shortest wavelength of said plurality of wavelengths of interest.

10. (Twice Amended) A method for displaying a color image comprising the steps of:

focusing light, from a light source having a plurality of wavelengths of interest, using a plurality of focusing elements;

illuminating a multilevel optical phase element with light focused by said plurality of focusing elements, said multilevel phase element dispersing [light] each wavelength of

interest from said plurality of focusing elements by diffraction into a plurality of diffraction orders and [focusing] projecting the dispersed light onto an imaging plane; and

actuating a light modulating display in the imaging plane having a plurality of pixel elements, each said pixel element assigned to transmit a predetermined spectral region, so as to receive said dispersed light from said multilevel optical phase element.

11. (Twice Amended) The method of claim 10 [further comprising providing] wherein said plurality of focusing elements [including] includes a plurality of lenslets and wherein said display is positioned at a distance Z from said multilevel optical phase element, wherein Z is determined by the relationship:

$$\frac{2T^2 Z_S}{3\lambda_{long} Z_S - 2T^2} < Z < \frac{2T^2 Z_S}{3\lambda_{short} Z_S - 2T^2}$$

wherein T is the periodicity of said multilevel optical phase element, Z_s is equal to the distance between said multilevel optical phase element and said lenslets minus the focal length of said lenslets.

12. (Twice Amended) The method of claim [11] 10, wherein said plurality of focusing elements includes a plurality of lenslets and wherein said display is positioned at a distance Z from said multilevel optical phase element, wherein Z is determined by the relationship:

$$\left[\frac{2T^2 Z_S}{3\lambda_{long} Z_S - 2T^2} < Z < \frac{2T^2 Z_S}{3\lambda_{short} Z_S - 2T^2} \right]$$

$$\frac{T^2 Z_s}{3\lambda_{long} Z_s - T^2} < Z < \frac{T^2 Z_s}{3\lambda_{short} Z_s - T^2}$$

---

wherein T is the periodicity of said multilevel optical phase element, Z_s is equal to the distance between said multilevel optical phase element and said lenslets minus the focal length of said lenslets.

15. (Twice Amended) [A system] <u>An apparatus</u> for displaying a color image comprising:

a light source emitting a plurality of wavelengths of interest;

a multilevel optical phase element positioned to receive light from said light source, said multilevel phase element dispersing [light] <u>each wavelength of interest</u> from said light source by diffraction <u>into a plurality of diffraction orders</u> and [focusing] <u>projecting</u> the dispersed light onto an imaging plane; and

a light modulating electronic display positioned in the imaging plane and having a plurality of pixel elements, each said pixel element assigned to transmit a predetermined spectral region, positioned within the near field region of said multilevel optical phase <u>element</u> so as to receive said dispersed light from said multilevel phase element.

16. (Twice Amended) The [system] <u>apparatus</u> of claim 15 wherein said display is positioned at a distance Z from said multilevel optical phase element, wherein Z is determined by the relationship:

$$\left[\frac{T^2}{3\lambda_{long}} < Z < \frac{2T^2}{3\lambda_{short}} \right]$$

$$\frac{2T^2}{3\lambda_{long}} < Z < \frac{2T^2}{3\lambda_{short}}$$

wherein T is the periodicity of said multilevel optical phase element, λ_{Long} is the longest wavelength of said plurality of wavelengths of interest and λ_{Short} is the shortest wavelength of said plurality of wavelengths of interest.

18. (Twice Amended) The [system] apparatus of claim [16] 15 wherein said display is positioned at a distance Z from said multilevel optical phase element, wherein Z is determined by the relation:

$$\frac{T^2}{3\lambda_{long}} < Z < \frac{T^2}{3\lambda_{short}}$$

wherein T is the periodicity of said multilevel optical phase element, λ_{Long} is the longest wavelength of said plurality of wavelengths of interest and λ_{Short} is the shortest wavelength of said plurality of wavelengths of interest.

19. (Twice Amended) The [system] apparatus of claim 16 wherein said light source has a polychromatic spectrum.

20. (Twice Amended) The [system] apparatus of claim 15 wherein said light source comprises a plurality of subsources each subsource having a different spectral distribution.

21. (Twice Amended) The [system] apparatus of claim 20 wherein each said subsource is a light emitting diode.

22. (Twice Amended) The [system] apparatus of claim 20 wherein each said subsource is a laser.

23. (Twice Amended) The [system] apparatus of claim 15 wherein said multilevel optical phase element is multilevel in two orthogonal directions.

24. (Twice Amended) A [system] apparatus for displaying a color image comprising:

a light source having a plurality of wavelengths of interest;

a plurality of focusing elements positioned to focus light from said light source;

a multilevel optical phase element positioned to receive light focused by said plurality of focusing elements, said multilevel phase element dispersing [light] each wavelength of interest from said plurality of focusing elements by diffraction into a plurality of diffraction orders and [focusing] projecting the dispersed light onto an imaging plane; and

a light modulating electronic display positioned in the imaging plane and having a plurality of pixel elements, each said pixel element assigned to transmit a predetermined spectral region, positioned so as to receive said dispersed light from said multilevel optical phase element.

25. (Twice Amended) The [system] apparatus of claim 24 wherein said plurality of focusing elements comprises a plurality of lenslets and wherein said display is positioned at a distance Z from said multilevel optical phase element, wherein Z is determined by the relationship:

$$\frac{2T^2Z_s}{3\lambda_{long}Z_s-2T^2} < Z < \frac{2T^2Z_s}{3\lambda_{short}Z_s-2T^2}$$

wherein T is the periodicity of said multilevel optical phase element, Z_s is equal to the distance between said multilevel optical phase element and said lenslets minus the focal length of said lenslets, λ_{long} is the largest wavelength of said plurality of wavelengths of interest and λ_{short} is the shortest wavelength of said plurality of wavelengths of interest.

26. (Twice Amended) The [system] apparatus of claim [25] 24 wherein said plurality of focusing elements comprises a plurality of lenslets and wherein said display is positioned at a distance Z from said multilevel optical phase element, wherein Z is determined by the relationship:

$$\left[\frac{2T^2Z_S}{3\lambda_{long}Z_S-2T^2} < Z < \frac{2T^2Z_S}{3\lambda_{short}Z_S-2T^2} \right]$$

$$\frac{T^2Z_S}{3\lambda_{long}Z_S-T^2} < Z < \frac{T^2Z_S}{3\lambda_{short}Z_S-T^2}$$

wherein T is the periodicity of said multilevel optical phase element, Z_s is equal to the distance between said multilevel optical phase element and said lenslets minus the focal length of said lenslets, λ_{long} is the largest wavelength of said plurality of wavelengths of interest and λ_{short} is the shortest wavelength of said plurality of wavelengths of interest.

27. (Twice Amended) The [system] apparatus of claim 24 wherein said multilevel optical phase element is constructed such that a magnification produced by said plurality of lenslets produces a dispersion element substantially equal to the dimensions of each pixel element in said display.

28. (Twice Amended) The [system] apparatus of claim 27 wherein said magnification (M) is given by the equation:

$$M = 1 + \frac{Z}{Z_S}$$

wherein T is the periodicity of said multilevel optical phase element, Z is the distance between said multilevel optical phase element and said display and Z_s is equal to the distance between said multilevel optical phase element and said lenslets minus the focal length of said lenslets.

29. (Twice Amended) The [system] apparatus of claim 24 wherein said multilevel optical phase element is multilevel in two orthogonal directions.

30. (Twice Amended) The [system] apparatus of claim 24 wherein said light source comprises a plurality of subsources each subsource having a different spectral distribution.

31. (Twice Amended) The [system] apparatus of claim 30 wherein each said subsource is a light emitting diode.

32. (Twice Amended) The [system] apparatus of claim 30 wherein each said subsource is a laser.